# A Comparative Study of Color Change Assessment for Frozen Ground Beef Using Traditional Colorimeter and Digital Image Analysis

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# Abstract

Color change of frozen meat is a major quality concern since loss in redness indicates protein oxidation. Compared with traditional colorimeter methodologies, digital image processing not only saves in labor costs but also leads to more objective measuring results. The goals of this study were to determine if a traditional colorimeter methodology and digital image processing software correlate with each other, then to assess the variability within each method.

Beef patties were obtained from an extended shelf-life research project for five consecutive months, and color measurements were taken under Standard Illuminant $D_{65}$. Portable colorimeter took reflected color measurements on each patty and displayed in CIELAB color space, while image processing software analyzed pictures exported from a digital camera, and results were converted from RGB to CIELAB color space.

Average a* (Green-Red color scale) values from 3 selected patties under a certain storage temperature, among both methodologies, were scattered from 3.2 to 20.3, corresponding to month 1 – month 5 in the extended shelf-life study. A good correlation of average a* values between two methodologies were discovered under frozen storage and different temperature conditions. Standard deviations of a* values scattered from 0.07 to 4.73 among two methodologies. Results showed that third fourths of standard deviation values from digital image analysis method were around 0-0.5 whereas the colorimeter method had higher values of 0.5-1.0, which represented less variability from patty to patty within digital image analysis method. In addition, digital image analysis method also had less variable, or, more concentrated standard deviation values when measuring color attributes under frozen storage and different temperature conditions. Digital image analysis method, in those experimental settings, illustrated less variability, in other words, more robustness when it was used to measure color in continuously changing conditions, compared to traditional colorimeter.

This study is of importance because it could possibly inform the potentials of digital image analysis, which may be more time-consuming but can lead to more reliable results, compared to traditional colorimeter methodology.

## Introduction

When purchasing meat products in grocery stores, consumers rely on the bright red surface color as an indicator of the wholesomeness and freshness (Suman and Joseph 2013). They also focus on the color changing of the meat during refrigeration storage with strong intentions to discard when surface color becomes undesirable (Suman et al. 2014).

Past researches have shown the color attributes tend to be strongly associated with myoglobin (Hughes et al. 2014). Myoglobin, as the heme protein that is essentially responsible for the meat color, has its specific chemistry. The reason for meat color change involves protein oxygenation and oxidation, or, the conversion of several states of myoglobin, governed by multiple factors either in the product or from the environment (Kitahara et al. 1990; McKenna et al. 2005; Seyfert et al. 2006). Myoglobin color in fresh cut raw meat surface under very low oxygen tension is dark purplish-red or purplish-pink (Boles and Pegg 2010; AMSA 2012). Deoxymyoglobin is a purplish-red color. Oxymyoglobin, which has a bright-red color and high consumer acceptance, is formed when oxygenation happens, where oxygen occupies the sixth coordinate of heme iron (Suman and Joseph 2013). However, if the concentration of oxygen is rather low and metal ions are present, then oxidation of myoglobin results in the formation of metmyoglobin (MetMb), a brown pigment in cooked meats. Accumulation of MetMb discolors surface of the fresh meat (Ledward 1971; Bekhit et al. 2003), and the color change of bright red to unappealing brown results in the main quality reduction from consumer’s point of view. Human color perception is complex and environment dependent; thus analytical tools, such as colorimeter, are commonly utilized for accurate color communication. Quantitative digital image processing, however, is becoming a potentially strong alternative for traditional colorimeters with advantages of the flexible measurements, the digitally stored data, and the decreased cost of processing (Twogood and Sommer 1982).

Based on previous experience, it was hypothesized that digital image processing would produce less variable and more robust results of color measurement, compared to colorimeter, because of its ability to include larger measuring area, and thus reduce the effects of non-uniform color present in meat patties.

## Objective

The goal of this study was to visualize and assess the color change of frozen ground beef patties in order to determine if the color perception results from a traditional colorimeter methodology and a digital image processing software correlate with each other, then to determine if digital image analysis can replace colorimeter in our experimental settings.

## Methods

*Frozen Beef Patties Storage*

Beef patties used for this study were obtained from an extended shelf-life research project for five consecutive months. Based on that, it was feasible to include data of reflected color measurements under three storage temperatures (-10°C, -15°C, -20°C) in every month, with three patty replicates for each temperature in one month.

*Light source and two methodologies for color perception*

All reflected color measurements were taken under wall-mounted lightings in the laboratory, which was scientifically interpreted as CIE Standard Illuminant $D_{65}$. It imitates natural daylight and provides a single standard for "white light", thus has extensive applications for visually demanding tasks such as colorimetry. Regardless of the detector to be human eyes or analytical tools with subsequent calculations, $D_{65}$ is stable and consistent as a light source which can represent average daylight.

A portable and handheld colorimeter (Konica Minolta CR-300 Chroma Meter) was used to take reflected color measurements, with three locations randomly selected on one patty. With internal data processors, it is capable of measuring a wide variety of surfaces with good correlation with color, as reported in CIELAB color space on the display. Measurement for every patty included data three circular spots, with the total measuring area of 150 $mm^2$, compared to area of the complete patty to be 4000 $mm^2$.

Digital camera (Canon Rebel T6) was used to capture pictures for every patty. Raw images were processed and imported into the digital image analysis software – ImageJ, as the format of Joint Photographic Expert Group (JPEG). By defining and creating a Region of Interest (ROI) on digital pictures of each patty, ImageJ was able to convert the information of color which was detected by camera, into quantitative values in RGB color space for every patty replicate. ROI rendered ImageJ method an increased capability of incorporating a larger measuring area on each frozen patty, up to 2300 $mm^2$ out of 4000 $mm^2$.

L*a*b, as three numerical values, expressed color in the lightness, the green-red and blue-yellow color components, respectively. Compared to RGB color space, CIELAB was more independent of what kind of equipment had been applied, as well as had more uniform perceptions in terms of the similarity to human color vision. Therefore, MATLAB rgb2lab function was used to convert RGB data into L*a*b data, making standardized notations among both methodologies which were simpler to analyze and compare.

*Data processing*

Scatter graph with trendline as well as Box and Whisker plot on Microsoft Excel were used to visualize the correlation and variability between results from traditional colorimeter and digital image analysis in terms of a* values (i.e., redness of frozen beef patties).

## Results and Discussion

*Correlation between two methods*

Data of a* values reported on the colorimeter display, as well as converted from RGB color space on ImageJ, was recorded and plotted. As shown in Figure 1, average a* (Green-Red color scale) values from 3 selected patties under a certain storage temperature (-10°C, -15°C or -20°C), among both methodologies, were scattered from 3.2 to 20.3, corresponding to month 1 – month 5 in the extended shelf-life study. A trendline of linear regression was created, and it summarized the relationship between converted a* values from Image J and a* values from colorimeter, with a R square of 0.9383. This showed a good correlation of average a* values between two methodologies, with all data points from extended five-month frozen storage and three different temperature conditions.

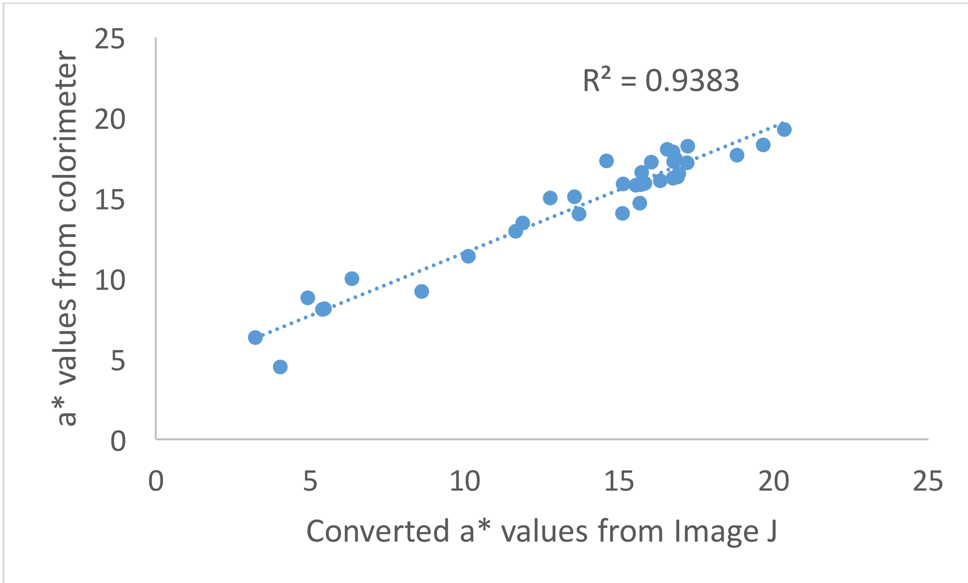


Figure 1. Relationship shown in Linear Regression of converted a* values from Image J and a* values from colorimeter

*Variability within each method*

Standard deviations of a* values from 3 selected patties of each storage chamber in every specific storage time point (e.g., -15°C storage temperature, at the end of month 1) were calculated and plotted. It was scattered from 0.07 to 4.73 among two methodologies. Specific values of standard deviation indicate differences between three patty replicate, however, to better visualize the variability of redness measurement within each method, Box and Whisker plot was created to graph the minimum, first quartile, medians, third quartile, and maximum of standard deviation values (Y axis) in ImageJ and colorimeter method, respectively. Specifically, this demonstrated the distribution of standard deviation values from the lowest to the highest, such as first quartile box means that one fourth of overall cumulated standard deviation values were within the Y axis limit of the box. Thus, it could be noticed through the locations of quartile boxes that third fourths of standard deviation values from digital image analysis method were around 0-0.5 whereas the colorimeter method had higher values of 0.5-1.0. The numerical values represented less variability from patty to patty within digital image analysis method, nevertheless, besides that, the Box and Whisker plot also indicated that digital image analysis method showed more compact quartile boxes which further represented statistically less variable, or, more concentrated standard deviation values when measuring color attributes in different conditions (i.e., three storage temperatures and five-month extended storage time). Digital image analysis method, in these experimental settings, illustrated less variability, in other words, more robustness when it was used to measure color in continuously changing conditions, compared to traditional colorimeter.

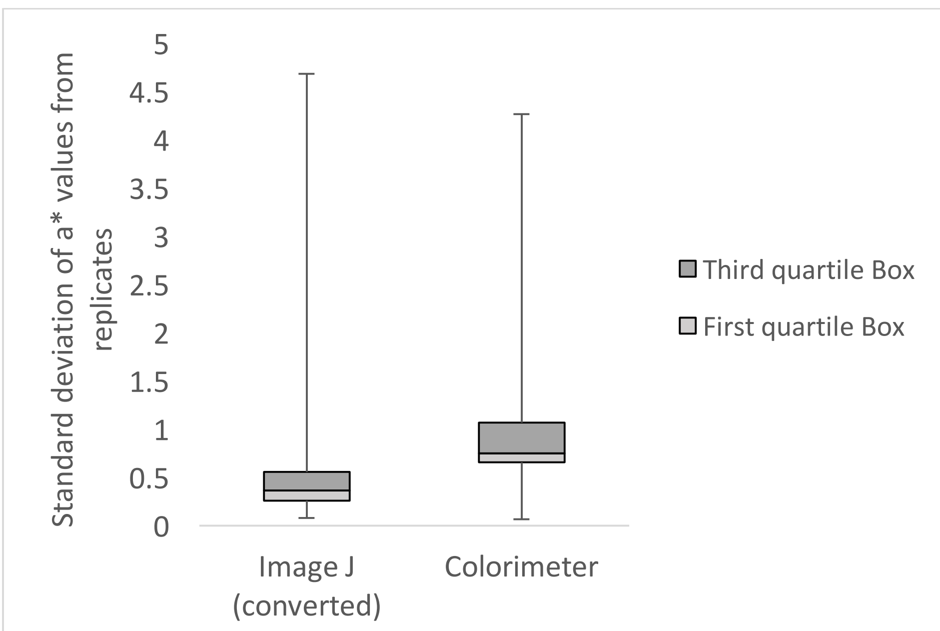


Figure 2. Standard deviation of converted a* values (Image J) and a* values (colorimeter) from 3 selected patties, shown in Box and Whisker plot

There were some limitations in this study which potentially need future work including the necessity to reproduce the experiments on different types of meat products. Also, raw image processing was performed to export images from the digital camera, which left some space for improvements on information preservation of those raw images, or the overall investigation methods.

## Conclusions

Results suggested that both traditional colorimeter and digital image analysis with the software ImageJ had similar a* value averages which indicated a good correlation between two methodologies. On the other hand, digital image analysis method had less variable and overall smaller standard deviations of three patty replicates from a certain storage temperature along the five-month extended storage while colorimeter method had a wider distribution and overall larger standard deviation values. Correlation between two methods and variability within each method demonstrated the advantages of computer based digital image analysis method in the experimental settings used by this study. This study is of importance because it could possibly inform laboratories that are using traditional colorimeter for color assessment at present, the potentials of digital image analysis, which may be more time-consuming but can lead to more reliable results. As for food industry, digital image analysis can have a broader application and utilization based on companies' informed decisions.

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